OPTIMIZATION OF LINE SIZING OF THERMAL POWER STATION

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Abstract

General layout and location of steam consuming equipment is of great importance in efficient distribution of steam. Steam pipes should be laid by the shortest possible distance rather than to follow a building layout or road etc. However, this may come in the way of aesthetic design and architect's plans and a compromise may be necessary while laying new pipes. Apart from proper sizing of pipe lines, provision must be made for proper draining of condensate which is bound to form as steam travels along the pipe.

Keywords*-piping design, line sizing, steam velocity, pressure drop, stress analysis*

I. INTRODUCTION

The basic concept of a piping design is to safely and economically transport steam, brine, or two- phase flow to the destination with acceptable pressure loss. The piping associated with plant can be divided in piping inside the plant and the piping in the steam field.

Water pipe sizing is based on velocity, pressure drop and capital cost. Low fluid velocity is usually correlated to low pressure drop, however, this results to large diameter pipes which are generally expensive. High fluid velocity usually travels to small diameter pipes, which reduces capital cost but results to unacceptable high pressure losses. Within the limit of acceptable velocity range for a given service, a compromise needs to be made between pressure drop and capital cost. This is often termed as "sizing the pipe by economic pressure drop".

Factors needed to be considered for water pipe design are scrubbing the water, velocity of water, corrosion allowances, pressure drop, pressure and temperature.

II. DESIGN PROCEDURE

I. The determination of the problem, which includes:
a. The characteristics of the fluid to be carried,
including the flow rate and the allowable head loss;
b. The location of the pipelines: its source and destination,
and the terrain over which it will pass, the location of
separator station and the power plant;

c. The design code to be followed; and
d. The material to be used.

II. The determination of a preliminary pipe route, the line Length and static head difference.
III. Pipe diameter based on allowable head loss;
IV. Structural analysis:
a. Pipe wall thickness; and
b. Stress analysis.

V. The stress analysis is performed in pipe configuration until compliance with the code is achieved.
VI. Support and anchor design based on reaction found in
the structural analysis.
VII. Preparation of drawings, specification and the design report.

TYPES OF LINE SIZING:

- Fluid velocity.

- Pressure drop

PIPELINE SIZING ON STEAM VELOCITY:

If pipe work is sized on the basis of velocity, then calculations are based on the volume of steam being carried in relation to the cross sectional area of the pipe.
For dry saturated steam mains, practical experience shows that reasonable velocities are 25 - 40 m/s, but these should be regarded as the maxima above which noise and erosion will take place, particularly if the steam is wet.
Even these velocities can be high in terms of their effect on pressure drop. In longer supply lines, it is often necessary to restrict velocities to 15 m/s if high pressure drops are to be avoided.
Alternatively the pipe size can be calculated by following the mathematical procedure as outlined below. In order to do this, we need to define the following information:

Flow velocity (m/s) C
Specific volume (m3/kg) v
Mass flow rate (kg/s) m

Now as per continuity equation

$$m = \frac{A * C}{v}$$

& $A = \frac{\pi}{4} d^2$

$$d = \sqrt{\frac{4 * m * v}{\pi * C}}$$

STRUCTURAL ANALYSIS:

Circumferential stress or Hoop stress due to pressure and vacuum is considered for sizing and selecting the pipe with suitable wall thickness.

Equations for pipe stress analysis are given in the design code. The first step is the determination of wall thickness required by ASME B31.1 (Power Piping):

$$T_m = \frac{PDo}{2(\sigma + Py)} + A$$

Where Tm = Wall thickness in millimetres;

P = Design pressure in kilopascals;
D_o = Pipe outside diameter in millimetres;

σ= Allowable stress in kilopascals;
y = 0.4, for most geothermal application it based on temperature range and steel type;
A = 1 mm corrosion and erosion allowance.
Stress analysis should be carried out for the following load cases for compliance with the code requirement and support load calculation. ASME B31.1 POWER PIPING requires that a pipeline shall be analyzed between anchors for the effects of:
1. Sustained loads, Gravity + Pressure;
2. Operation loads, thermal expansion stress alone or thermal expansion stress + sustained loads;
3. Occasional loads, sustained loads + seismic load or wind load perpendicular to the general alignment of the pipe;
4. Occasional loads, sustained loads + seismic loads along the general direction of the pipe;
5. Reverse the direction of seismic or wind loads;
6. Modes of thermal operation need to be considered in the analysis.
In addition to this, an analysis should be carried out for zero friction to determine the maximum load on the anchors in the event of an earthquake. Other dynamic loads that can be considered are fluid hammer effects, thrusts from safety valves, and slugging flow.

Example: main steam line

Parameter for main steam line
P=86.9 bar, P_d=1.2*86.9 =104.28
T = 516 °c, T_d = 516 + 10 =526 °c

m = 78.8 TPH = 21.88 kg/s
Now from steam table specific volume of stem flowing through the pipe at design P_d & T_d ;
v = 0.0401 m^3/ kg
now from chart of velocity allowable for the pipe assume velocity for given parameter
C = 50 m/s

$$d = \sqrt{\frac{4 * 21.88 * 0.0401}{\pi * 50}}$$

d = 0.149 m

Determining the mass flow rate of steam

The layout of a typical orifice plate is shown in Figure 1 where D is the inside diameter of the pipe and Do is the diameter of the orifice. The pressure taps may be placed in several locations as shown above, but the location of the pressure tap will influence the empirically determined flow coefficient. The values of the flow coefficient must be consistent with the location of the pressure taps.

The base flow may be described by using the laws of conservation of mass and momentum. From the conservation of mass we get that the mass flow through the pipe will equal the mass flow through the orifice:

$$\rho V A = \rho_o V_o A_o$$

Where ρ is the fluid density, V is the average velocity at a particular location, A is the cross-sectional area, and the subscript O denotes parameters at the orifice. The conservation of momentum may be reduced using a number of assumptions to the Bernoulli equation:

$$P + \frac{1}{2}\rho V^2 = P_o + \frac{1}{2}\rho_o V_o^2$$

The density of the fluid is assumed to change very little in the portion of the tube of interest. This assumption works well for liquids, but you must be careful when using vapor.

In order to express the pressure drop across the orifice in terms of the velocity and fluid density, the conservation of momentum equation is rearranged.

$$P - P_o = \frac{\rho}{2}\left(V_o^2 - V^2\right) = \frac{\rho V_o^2}{2}[1 - \left\{\frac{V}{V_o}\right\}^2]$$

From conservation of mass, equation , the ratio of the velocities is inversely proportional to the crosssectional area ratio,

$$\frac{V}{V_o} = \frac{A_o}{A}$$

Substituting this equation into above equation and solving for the velocity results in the following expression:

$$\mathbf{V_o} = \sqrt{\frac{\mathbf{2(P - P_o)}}{\boldsymbol{\rho}[\mathbf{1} - \left(\frac{\mathbf{A_o}}{\mathbf{A}}\right)^2]}}$$

The mass flow rate, ρ V A, is:

$$\dot{m}_{ideal} = \frac{A_o}{\sqrt{[1-(\frac{A_o}{A})^2}} A\sqrt{2\rho(P-P_o)}$$

Example of drain calculation :

Consider HP heater drain line pressure & temperature of drain line is 21.715 bar and 342°C respectively ;so from the steam table we get enthalpy of steam in line is 3117.56 kJ/kg.

Now pressure of the steam after orifice is 0.4 bar and the diameter of the orifice for given parameter is 7mm (d_o)

Therefore

$A_o = 38.48\ mm^2$ A = 9160.8 mm^2

Now mass flow rate of steam after orifice

$$\dot{m}_{ideal} = \frac{0.003848 * 10^{-2}}{\sqrt{[1-\left(\frac{38.48}{9160.8}\right)^2}} \sqrt{2 * 1000(21.715 * 10^5 - 0.4 * 10^5)/9.81}$$

$\dot{m}_{ideal}$ = **0.80 kg/s**

III. RESULT ANALYSIS

EFFECTS OF OVERSIZING AND UNDERSIZING PIPEWORK:

Over sizing of pipe work: [IF ALS>CLS]

- The pipes will be more expensive than necessary.
- A greater volume of condensate will be formed due to greater heat loss.
- Poorer steam quality and ultimate heat transfer due to the greater volume of condensate formed.
- Higher installation costs.
- Condensation of steam is increased.
- Due to more condensation, it affect the life of the steam trap.
- Increase weight of the pipeline.
- It require more time in supply of steam to process plants.
- Overall cost of the system is increased.

Under sizing of pipe work: [IF ALS<CLS]

- Higher steam velocity and pressure drop creating a lower pressure than required at point of use.
- Risk of steam starvation at point of use.
- Pipe erosion is increased.
- Erosion of the pipe can cause flashing of steam and water hammering effect.
- Life of the pipe is decreased.

III. CONCLUSION

- We have given actual line diagram of definite power plant.
- We have done line sizing.
- We have optimized the velocity in the pipe, so that will increase life of pipe.
- Economical consideration by preventing pipe from over sizing & under sizing

- With help of this, we can recommend class of orifices, valves and steam straps with accordance to ANSI B31.1

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